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ABSTRACT

This document actually consists of two state-of-the-art reviews on the use of calculators in education, one prepared in April 1978 and the second in May 1979. Each presents a concise summary of current status, with sections elaborating on the extent of use of calculators in schools, research on calculator effects, the development of instructional materials, and continuing concerns for research and development effort. References are included. (MS)

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The Use of Calculators in Pre-College Education: A State-of-the-Art Review*

Marilyn N. Suydam

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While no dramatic changes have characterized the situation during the past year, the use of calculators in schools continues to increase. Requests for information on calculator materials, attendance at workshops, and correspondence from teachers using calculators indicate that calculators are "slowly but surely" being assimilated into the instructional process. Whether or not to use calculators in classrooms is still an issue for some teachers and parents, but people are more accustomed to having the aids available. The calculator's role as an instructional tool is being recognized: it saves time spent on tedious calculation, and allows more time for developing mathematical ideas and for considering interesting content and problems. A new position statement from the National Council of Teachers of Mathematics cites other ways in which the calculator can aid instruction; the Council "encourages the use of calculators in the classroom as instructional aids and computational tools". While many still believe that students must master computational facts and procedures for addition and other operations before they use calculators, others are finding that there is some purpose for using calculators at each level.

Extent of Use in Schools

One of the most frequently asked questions is, "How many students are using calculators in schools?" Few data to supply an answer to this question have been published. Several studies were cited in the Calculator Information Center 1978 state-of-the-art review; the results of one national survey provide additional

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* This report concerns the period since April 1978, when the Calculator Information Center published a previous state-of-the-art review.

information. This survey, conducted during the winter of 1977 by Iris Weiss, queried a random sample of 1177 schools representative of the total school population across the country. They indicated increasing use as grade level increased:

	Grade Level			
	K-3	4-6	7-9	10-12
Schools having calculators	28%	36%	49%	77%
Teachers using calculators in science classes	2%	12%	10%	36%
Teachers using calculators in mathematics classes	6%	14%	30%	48%

Weiss added:

> Many teachers feel that calculators are not needed in their science classes (ranging from 47 percent in grades 10-12 to 69 percent in grades K-3), while between 14 and 19 percent indicate they are needed but not available. (p. 130)

For mathematics classes, the comparable data are:

	K-3	4-6	7-9	10-12
Calculators not needed	77%	44%	42%	33%
needed but not available	15%	39%	28%	18%

Unfortunately, these data are now two years old. It will be interesting to see what changes in the percentages occur as data are collected in 1979.

From a 1978 investigation with students in grades 2 through 6 in five midwestern states, Richard Shumway noted that the availability of calculators in the home increased during the project. At the beginning of the study, about 80% of the parents and 25% to 30% of the children had calculators at home. At the end, 90% of the parents and 45% of the children had calculators at home. This parallels previous information that when teachers encourage use of calculators in instruction, children are likely to acquire them to use

both in and out of school. As George Immerzeel, who has conducted workshops for many teachers, noted: "Almost any teacher who asks children to bring calculators finds that they do."

In several school districts, competency with calculators is included on the list of minimal competencies expected for graduation. The Ramona Unified School District in San Diego County, California, for instance, specified "The student can use a calculator to perform basic operations (+, -, x, ÷)" as one of nine competencies necessary to meet the goal of demonstrating "the ability to use basic mathematical processes necessary to function effectively in society."

Research on Calculator Effects

Almost 100 studies on the effects of calculator use have been conducted during the past four or five years. This is more investigations than on almost any other topic or tool or technique for mathematics instruction during this century, and calls attention to the intensive interest about this potentially valuable tool. Many of these studies had one goal: to ascertain whether or not the use of calculators would harm students' mathematical achievement. The answer continues to be "No". The calculator does not appear to affect achievement adversely. In all but a few instances, achievement scores are as high or higher when calculators are used for mathematics instruction (but not on tests) than when they are not used for instruction. Thus, many researchers working with students at all levels have paralleled the conclusion of Shumway and his co-investigators that "There were no measurable detrimental effects associated with use of calculators for teaching mathematics."

While a number of studies have replicated the finding that use of calculators does not appear to have harmful effects on the mathematical achievement of students who use calculators, many of the studies have not carefully documented how the students or teachers use the calculators. Often the calculator is used

"as the teacher or student sees fit" -- which may mean only for checking answers attained by paper-and-pencil computation or, worse, for activities which in actuality merely affirm that the calculator can calculate. Other researchers have turned to a more careful analysis of how the calculator is used.

Some of these researchers are exploring the role of the calculator in relation to problem solving, a primary goal of mathematics instruction. Billy Hopkins found that calculators helped students in a ninth-grade basic mathematics course to achieve better problem-solving scores than non-calculator users did. A study by Michael Kasnic provides additional evidence that calculators helped such students "compete successfully" with students of higher ability.

Charlotte Wheatley considered the effect of calculator use on problem-solving strategies employed by children in grade 5, while Glendon Blume reported on how seventh graders solved equations. It appears that different strategies and solution methods are used with calculators than are used without calculators. In particular, the calculator makes the exploration of hypotheses feasible. In conjunction with another problem-solving study, Marguerite Mason reported that "There was no evidence that the students become calculator dependent", thus providing a response to a concern of some parents.

Development of Instructional Materials

Teachers who want to use calculators find that they need specific materials if they are to integrate calculators into instruction. Therefore, individuals and groups have continued the development of materials designed specifically to make use of the unique capabilities of the calculator to promote desired mathematical objectives. One such instance was funded by the National Institute of Education. Gerald Rising and others at the State University of New York

at Buffalo are developing instructional materials for students in grades 11 and 12 in which the use of calculators is integrated. Problem solving and the development of mathematical skills and ideas are furthered by using the calculator.

In a number of school districts around the country, the development of materials is also proceeding. Funding from the Elementary and Secondary Education Act Title IV-C has aided districts from New England to California. Modules to accompany the regular curriculum, activity cards which supplement non-calculator work, and other materials are being designed by these groups. Most have in-service education components, in which teachers in the district are trained to use the materials.

For some years, George Immerzeel has been exploring the problem-solving strategies which children use and designing instructional materials to help them become better problem solvers. With his colleagues at the University of Northern Iowa and funding from Title IV-C, he has developed workbooks and sets of problems which incorporate the use of calculators to teach such specific problem-solving strategies as estimation and the use of tables and graphs.

Other groups have focused on meeting the needs of teachers for experiences with calculators and calculator materials. The North Carolina Department of Public Instruction has developed a kit of materials for in-service education. Transparencies, sets of problems, and other materials are included to aid in conducting workshops for teachers. At meetings of such organizations as the National Council of Teachers of Mathematics and the School Science and Mathematics Association, workshops are included on the program. Of even more interest are the numerous school districts across the country which have initiated workshops for teachers (and, in some cases, parents).

An increasing number of articles present ideas for integrating the calculator into the on-going instructional program. For instance, an article by Manfried

Olson provides examples that can be used to stimulate conjectures, lending themselves to algebraic proof. A calculator enables students to test cases which would have been fruitless, if not impossible, without a calculator.

The needs of specific groups of students are also being considered. A group of educational agencies, for example, has worked together to develop materials to help visually handicapped persons use calculators. Thus far they have produced some materials for adolescents and young adults, providing a self-instructional program with a focus on daily living and real-life problems. Similar materials are sought by those with other handicaps. The needs of low achievers at both the pre-college and college levels have also been considered; materials and procedures for calculator use by students who have not been particularly successful in mathematics are being developed.

Continuing Concerns

In June 1976, a conference was held to explore needed research and development with calculators; in January 1979, a second conference was sponsored by the National Institute of Education to specify in more detail the points made at the first conference as well as to explore additional needs. The participants strongly suggest that a reiteration of the concerns expressed at the first conference is vital. While a report of the conference has not yet been developed, it appears that, among other points, it will stress the need for:

- Research on how calculators can develop mathematical skills and concepts at all levels.
- Development of instructional materials which integrate the use of calculators
- Continuing evaluation of the effects of calculators on achievement and attitudes

- Continuing concern for the needs of all types of learners as they use calculators
- Emphasis on providing preservice and in-service teachers with calculator experiences

Another continuing concern is with the role of calculators on tests. In several other countries, calculator use has been allowed on standardized tests; this is not yet true in the U.S. There is a stalemate at present: it is not appropriate to use calculators on normed tests, since both tests and norms were developed without calculators being used. On the other hand, tests which allow the use of calculators will not be available until calculators are in much wider use. Teachers, however, have become aware of the need to develop classroom tests which assess mathematical ideas, rather than computational accuracy, when students use calculators.

Concluding Comment

Slowly but surely, the calculator is being incorporated into the school program at all levels. It is being recognized as an instructional tool which has certain capabilities. But it is not a pancea: it cannot resolve all the difficulties in mathematics instruction. Moreover, it has certain limitations; teachers must accept the responsibility for teaching children how and when to use calculators, and thus to be aware of its limitations. After all, students now in school will have calculators, or a similar computational tool, to use for the rest of their lives.

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The reports by Glendon Blume, Marguerite Mason, and Charlotte Wheatley are found in Research Reporting Sessions, 57th NCTM Annual Meeting. Columbus: ERIC/SMEAC, April 1979.

Copies of the NCTM Position Statement on Calculators in the Classroom are available from the National Council of Teachers of Mathematics, 1906 Association Drive, Reston, Virginia 22091.

CALCULATOR INFORMATION CENTER

April 1978

State-of-the-Art Review on Calculators:
Their Use in Education

Background

At approximately one-tenth the price they were four years ago, hand-held calculators are a bargain. They have progressed rapidly from being considered a status symbol to the point where, for many adults, they are considered a necessity. While not every household has a calculator, marketing figures indicate that over 80 million calculators have been sold in this country.

Increasingly, these data reflect sales not only to individual parents, who may let their children use the tool, but also sales to schools. Not surprisingly, the calculator was readily accepted at the college level -- as a tool in mathematics, engineering, science, and other courses, for all levels of students from remedial to advanced. At the secondary school level, there has also been a high degree of acceptance. The calculator was recognized as a tool which could help to save time spent on hand calculation and thus allow more time to be spent on mathematical ideas and on more interesting content and problems. Use of calculators is by no means incorporated into instruction by every secondary school mathematics teacher, but their use is widely allowed. The main question has been, "Should or shouldn't they be used on tests?", and even this is fading as an issue: teachers are using tests where calculators, available to all, are neither an aid nor a hindrance in terms of the goals being tested.

From the junior high school years downward, hesitancy about using calculators increases. Especially in classes for low achievers in the junior

high, there are many teachers who still hold firmly to the belief that students must master computational facts and procedures before they use calculators. On the other hand, an increasing number of teachers say, in effect, "Why should these students go on struggling to master what they've obviously had trouble mastering for the past six or seven or eight years? Why not let them use the calculator so they can go on to learn some real mathematics -- and maybe attain a different viewpoint about mathematics?"

In the elementary school, use of calculators is greater at the intermediate level (grades 4 through 6) than at the primary level. The most obvious reason for this is the widespread belief, held by both parents and teachers, that children should master the basic facts and the procedures for addition, subtraction, multiplication, and division before they use calculators. Associated with the tendency to use calculators may be the teacher's level of mathematical background: the greater the teacher's knowledge and confidence about mathematics, the more "comfortable" or secure he or she may feel with a tool that can process numbers so quickly. Another factor may be the firmer belief held by primary-level teachers in the role of manipulative materials in developing children's understanding of and competency with mathematical ideas and processes, as evidenced by the fact that the use of such materials is high in the primary grades but has tapered off by the fourth-grade level. Thus intermediate-level teachers may be more ready philosophically to use a tool which required no physical manipulation beyond key-pushing. (It might also be noted that fear of audiovisual equipment in general decreases as grade level increases.)

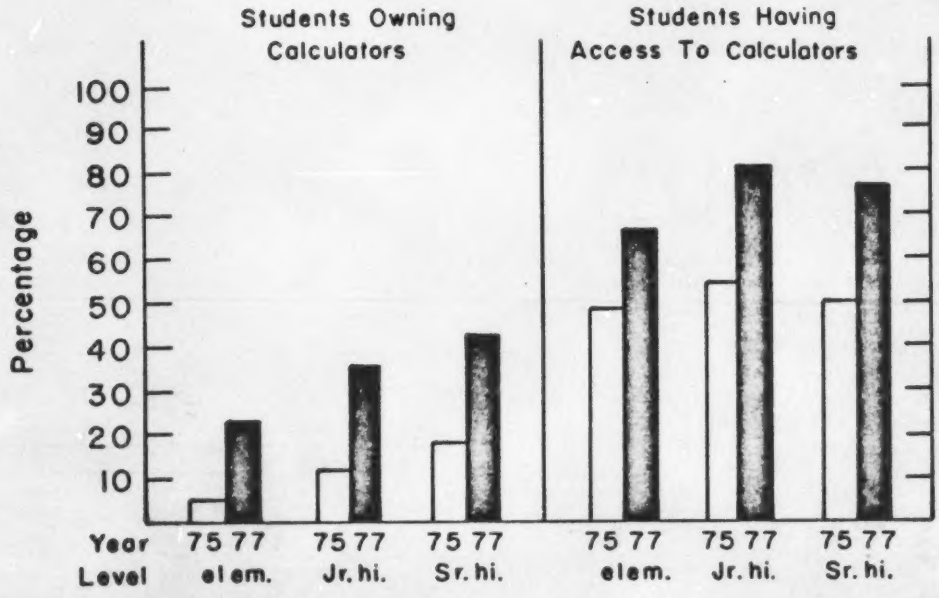
The "back-to-the-basics" bandwagon has also undoubtedly played a part in suppressing use of calculators at the elementary school level. As concern has been expressed by parents and school boards, teachers have re-emphasized the stress placed on work with computation. Extended practice exercises and

drill work have been viewed as the way to meet the demands for a more "traditional" type of arithmetic program. Energy that might have gone into exploring the use of calculator applications has been deflected to the development of drill-and-practice materials; the open-mindedness needed to incorporate instructional applications of calculators has been tamped by their "newness" in an era when "old" values are being given priority by a vocal sement of the population.

Extent and Type of Use in Schools

No data have thus far been cited about the extent to which calculators are being used in schools. The reason may be obvious: such data are not widely available. We do not know exactly how many students are using calculators in schools; we do not know exactly how many teachers are incorporating calculator use in the instructional program. We have only the results of a few relatively small-scale surveys, plus the perceptions of those who work with and observe school programs.

The following graph presents data from one such survey, conducted with over 22,000 students in the Shawnee Mission (Kansas) Public Schools.



It is one of the few studies in which data collected recently (1977) were compared with data collected earlier (1975). Terry Parks reported on both ownership and accessibility: substantial increases were found at each of the three school levels. The data reflect a pattern of increasing availability of calculators to students.

These data are paralleled in several other reports. It must be noted, however, that they may not be applicable to districts that have not collected data: the mere lack of collection of data may indicate less interest and less availability.

Just as data on the extent of the use of calculators are limited, so are data on the types of uses being made of calculators. But we do know that, at the elementary school level, four types of uses are predominant:

(1) Checking computational work done with paper and pencil.

(2) Games, which may or may not have much to do with furthering the mathematical content, but do provide motivation.

(3) Calculation: when numbers must be operated with, the calculator is used with the regular textbook or program.

(4) Exploratory activities, leading to the development of calculator-specific activities where the calculator is used to teach mathematical ideas.

At the secondary school level, the emphasis varies:

(1) Calculation, used whenever numbers must be operated with.

(2) Recreations and games.

(3) Exploration: because secondary school mathematics teachers' backgrounds are generally good, there is much more of this type of activity than at the elementary school level. In addition, the students who continue in higher-level courses are often intrigued to explore.

(4) Use of calculator-specific materials. There is at least one text integrating the use of calculators, with several others being field-tested.

Anna Graeber and several others at Research for Better Schools conducted a survey in 1977 of 1,343 teachers in Delaware, New Jersey, and Pennsylvania

in grades 1, 3, 5, and 7.

> In the first grade, calculators were used most frequently for drill; the next three most frequent usages were for checking, motivation, and remediation. Use of the calculator for drill decreased with grade level. Above first grade the most frequent usage was for checking. Motivation and word problems were the next most frequently reported uses for calculators at the higher grade levels.

Between 15 and 30 percent of the teachers indicated that they were using "instructional materials specifically designed for use with the calculator", although the nature of those materials is not noted.

Reasons For and Against Using Calculators

In a survey reported to the National Science Foundation in 1976 by Marilyn Suydam, reasons cited by educators and the authors of published articles for using or not using calculators in schools were listed. Literature published since then has affirmed the continuing acceptance of the reasons for using calculators:

(1) They aid in computation.

(2) They facilitate understanding and concept development.

(3) They lessen the need for memorization.

(4) They help in problem solving.

(5) They motivate.

(6) They aid in exploring, understanding, and learning algorithmic processes.

(7) They encourage discovery, exploration, and creativity.

(8) They exist: this pragmatic fact is perhaps the most compelling, as they appear in the hands of increasing numbers of students.

The reasons for not using calculators also continue to have pertinence:

(1) They could be used as substitutes for developing computational skills.

(2) They are not available to all.

(3) They may give a false impression of mathematics -- that it involves only computation and is largely mechanical.

(4) There is insufficient research on their effects.

(5) They lead to maintenance and security problems.

The first concern is one expressed most frequently by parents and other members of the public. They fear that students will become lazy and will not "make use of their brains -- a wonderful calculator if it is cultivated properly." But few educators believe that children should use calculators in place of learning basic computational skills. Rather, they express a strong belief that calculators can help children to develop and learn more mathematical skills and ideas than is possible without the use of calculators.

As one example of this, a survey of parents in West Chester, Pennsylvania in 1975 indicated that about half of the parents feared that calculators would hinder students' performance on basic skills -- but at least as many thought calculators would improve their children's attitudes toward mathematics. In another survey, parents were asked if calculators should be used in elementary schools; about three-fourths of them said "no". But when the question was changed to ask if calculators should be used along with paper-and-pencil computational work, over three-fourths said "yes".

Teachers' opinions about calculators have changed in recent years. In the Shawnee Mission survey already cited, teachers were asked, "Should calculators be used in schools by students?". In 1975, 65.2% said "yes"; in 1977, 71.9% said "yes". Analysis of reasons for responses indicated their awareness of how to use calculators as a tool to assist in teaching computational skills had increased. In 1975, teachers were concerned about the effect of calculators; by 1977, as ideas and guidelines had developed, concerns decreased. In the RBS study, however, the percentage of teachers who had used calculators at each level was far lower than might be anticipated: 3.9% at grade 1, 8.4% at grade 3, 19.4% at grade 5, and only 25.6% at grade 7. Obviously there is much variance in the use of calculators

at different locations. The effect of leaders who are actively interested in helping teachers learn how to use calculators as an instructional tool seems evident.

Research on Calculator Effects

Most educators believe that the use of calculators should not replace instruction on skills and concepts; rather, calculators are a useful teaching-learning device. Evidence from the research to date supports this contention. In most of the studies at the elementary school level, the data were collected to provide an answer (to parents and school boards, as well as to teachers) to the question, "Will the use of calculators hurt mathematical achievement?" The answer appears to be "No": in all but a few studies, achievement is as high or higher when calculators are used for mathematics instruction (but not used on tests) than when they are not used. But there is variability in the findings, depending in part on the test used: scores may not be as high for problem solving or for concept sections of a test. However, considering the fact that the curriculum was not changed to use the calculator to promote problem solving or concept development specifically, this may not be surprising. Unfortunately, it is unclear in the reports from such evaluations just how the calculator was used, so that specific ways in which the calculator might have been used to enhance problem solving or concept scores remains unknown. What we do know is that the calculator, in general, facilitates mathematical achievement across a wide variety of topics, and this finding is verified at both the elementary and secondary school levels.

In addition, there are a few studies which indicate that children learn basic facts and skills with the use of calculators, and they learn mathematical ideas (such as understanding of mathematical properties) with the use of calculators. Such research in the United States is supported by evidence from other countries, such as Britain and West Germany. There is also evidence

that children do not tend to use the calculator when they realize that it is unnecessary. For example, one researcher cited the example of 79 + 23 - 79 = ?; children did not use the calculator to find the result -- as many adults might have.

At the Wisconsin Center for Cognitive Learning, exploratory work has been underway for the past four years. Summarizing his investigations for the Center in 1976-77, Fred Weaver stated:

> At the second-grade level, teachers were given explicit suggestions regarding use of calculators in connection with their on-going mathematics programs, particularly when working with basic addition and subtraction facts and algorithms. At the third-grade level, an emphasis was placed upon the use of calculators in connection with mathematical properties and their applications with particular attention to doing-undoing ideas. At the seventh-grade level, emphasis was placed upon calculator algorithms for whole number situations.
>
> Generally, calculators facilitated instruction, making certain approaches to content more feasible than otherwise would have been the case. However, at each grade level some difficulty was observed in recording calculator algorithms.

His work has been concerned less with developing materials than with exploring the effect of the calculator on promoting mathematical learning. Several other projects sponsored by the National Institute of Education or the National Science Foundation have the same focus on learning rather than materials.

As the research is surveyed, it becomes evident that there is a need for many more studies to provide knowledge of how calculators can be used to facilitate learning.

Curriculum Development

Monies from federally funded programs, including Title IV of the Elementary and Secondary Education Act, as well as from NIE and NSF, are currently being devoted to the exploration of what uses of calculators are feasible and to the development of materials for children and teachers. For

example, the Columbus (Ohio) Public Schools have a grant under Title IV to develop materials for grades 4, 5, and 6, and are presently field-testing modules for a range of topics including place value, decimal computations, rounding, estimation, basic facts, and applications in measurement and money.

Materials are being developed by both individuals and groups. For instance, a group of teachers in the Minneapolis Public Schools produced a set of worksheets complete with objectives and teaching suggestions, designed for students in grades 9 and 10. The topics range from the decimal system to applications such as finding the cost of an oil change or charting population growth. The calculator is used as a tool to help children learn mathematical ideas, and as a computational device to help them to understand ideas and applications that they might not otherwise have been able to.

Several of the state mathematics councils have similarly involved members in developing materials. The Michigan Council of Teachers of Mathematics monograph provides a variety of activities for grades K-3, 4-8, and 9-12, with the mathematical objectives clearly specified. Unfortunately, in many other current publications, the calculator itself is being taught, not mathematics. Students learn some interesting things to do with a calculator, but instructional objectives may not be furthered in the process.

Other states are at the stage of incorporating recommendations on calculators in their curriculum guides. For instance, Indiana's 1977 publication states:

> Calculators certainly will have an impact on mathematics curricula. They may change not only the kinds of computational skills which are taught but the manner in which they are taught. It is our feeling that mathematics teachers and curriculum planners must incorporate calculators into regular classwork rather than ignore or banish them. Teachers must find effective uses at all levels from primary grades to calculus.

The guide then suggests ways to use calculators: to reinforce computational

skills, to improve estimation skills, to aid in teaching place value, to develop number concepts, to solve problems with factual data, and to extend textbook problems using more realistic numbers are among the points cited.

A teacher in Fairview Park, Ohio, provides a typical illustration of what an individual teacher may do. When her school received 12 calculators, she put together a unit for her sixth-grade class. She wanted the children not only to become familiar with the functions of the calculator, but also to use the calculator to solve everyday problems and to learn more about number patterns. She used the overhead projector to teach the children how to use the calculator, and made posters, worksheets, task cards, games, and other materials. She found student interest high, with many students gaining confidence in their problem-solving and estimating skills.

The majority of the materials being published contain activities for using the calculator to promote existing curricular ideas. Some of the recommendations of the 1976 NIE/NSF Conference on Needed Research and Development on Hand-Held Calculators in School Mathematics concerned curriculum development for the long-range future. Although little has been published that stretches the curriculum to new bounds, NIE is supporting the development of some future-oriented prototypic curricula that integrate calculator use.

Next Steps

We need to know much more: not just what calculators can do, but what it is possible for them to do given specified curricular and instructional options. We need to know how learning is affected by the use of calculators and how mathematics can be taught differently because of the existence of a new tool. As one respondent to a survey at the 1977 Annual Meeting of the National Council of Teachers of Mathematics noted:

> The calculators' relationship to problem-solving ability is a question of vital concern. Although the research reported

> in Suydam's 1976 report for the NSF shows conflicting reports about calculator effects on problem solving, all of the research . . . had the common element that the calculator was an adjunct to units in problem solving -- it was not incorporated into a specific problem solving strategy. This appears to be the best hope for meaningful use of the calculator -- by incorporating it into a specific strategy.

Summary

The use of calculators in education is increasing, although there is some concern and resistance at all levels. The fact that they have become more widely available and that children will use them in their daily lives throughout life makes their use in schools seem imperative to many people. Others fear that growing dependence on calculators will be harmful. However, there is initial evidence that calculators can be used to further the development of mathematical ideas and skills. The efforts of both individuals and groups are focused on studying the effects of calculator use and on developing needed materials. The calculator is not and will not be ignored as a useful learning tool.

Prepared by Marilyn N. Suydam, Calculator Information Center.

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Additional references are found in the bulletins distributed by the Calculator Information Center, 1200 Chambers Road, Columbus, Ohio 43212.